EELE445 Lab 4: Sampling, Aliasing and PAM using the LM311

Purpose
The purpose of the lab is to show the effects of sampling and aliasing using the LM311 open collector comparator as a sampling mixer. The mixer output is analyzed in the time domain and the frequency domain. The results are then compared to the predicted theoretical response of the circuit. Your instructor will verify your circuit and test setup to help you.

Components Required:
- Small bread-board to build the circuit on(or just use clip leads directly)
- 3 ea 10Kohm resistors
- 1ea LM311 Open Collector Voltage Comparator IC
- 1 10uf 5V or larger electrolytic capacitor (if needed) for power supply bypass
- Lab 4 Matlab program

Reference Sources

Couch 3-2, fig 3-2, fig 3-3 on natural sampling, Example3_01.m textbook Matlab file, National Semiconductor LM311 Data Sheet

Prelab
- $w(t) = 1 + \cos(2\pi 2.5 \times 10^3 t)$ Signal input. The DC is added so we can build the sampler using a single +5V supply. What is the Nyquist sample rate for this signal?
- Let $s(t) = \sum_{k=-\infty}^{\infty} \Pi\left(\dfrac{t - kT_s}{\tau}\right)$ for natural sampling. The sample rate is 1.5 time the Nyquist rate and the s(t) duty cycle is 10%. What is the sample frequency (or rate), what is the pulse width, and what is the duty cycle d?
- From fig 3-3 in the text find and sketch the spectrum from DC to 25 KHz of the sampled signal $v_s(t)$ of a 2V$_{p-p}$, 2.5 KHz sine wave Natural Sampled at 1.5 times the Nyquist rate. The s(t) sampling signal has a 10% duty cycle. Be sure to indicate the amplitudes of the spectral components.
- Look over the LM311 data sheet before lab.

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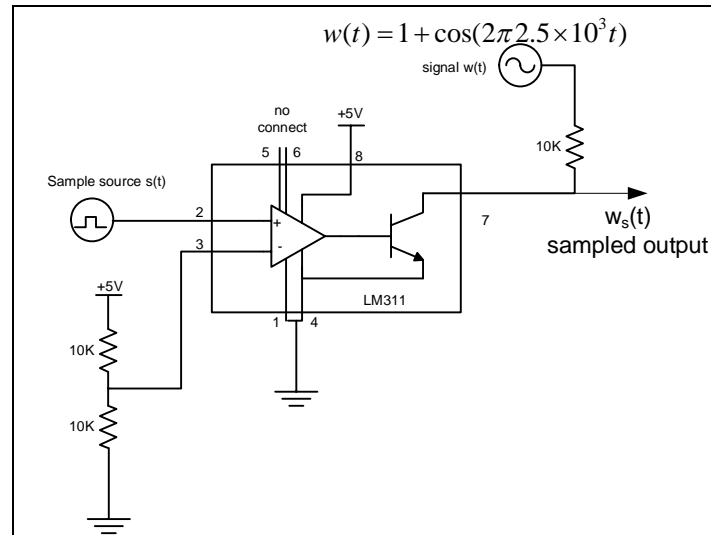
$$w(t) = 1 + \cos(2\pi 2.5 \times 10^3 t)$$

Figure 1

METHOD:

Normal Sampling without Aliasing

1. Build the circuit shown in figure 1. Use one channel of the function generator for s(t) with an amplitude of 0 to 5 volts and use the second channel of the generator for w(t). Verify that the circuit output is an amplitude-modulated series of pulses, PAM (pulse amplitude modulation). Use a duty cycle of 10% for the sampling signal pulses.

   a) Observe the output PAM signal with an oscilloscope. Sketch the signal.
   b) Display the output spectrum using the FFT of the scope. Adjust the sampling rate and FFT span of the scope to display a spectrum of DC to 25 kHz frequency range with minimum aliasing of the harmonics. Record the frequency and amplitude of each spectral line from DC to 25 KHz. You will compare your measurements to the theoretical values in your report.
   c) Make appropriate plots in your lab notebook. Write a brief description of what the plots indicate.
   d) Show that a reasonable LPF can recover w(t).

Normal Sampling with Aliasing

2. Decrease the sample rate of S(t) so that aliasing occurs. Change the sample rate on rate so that you have a spectral line at 1.5 kHz and another at 2.5 kHz.
   - Show that you can tell which of these two is the aliasing signal is by making small changes of the 2.5 KHz signal frequency (does the frequency of the spectral line change by df or by –df).
   - Make appropriate sketches and notes in your lab notebook and show your instructor.

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3.   Return the pulse rate to the original value to remove the aliasing. Make your sampling pulse wider by increasing the duty cycle of S(t).
- Identify the presence of the sinc function distortion of the output spectral components.
- Again show your instructor and make plots in your notebook of the time and frequency domain data.

Normal Sampling with Aliasing of the Harmonics of a Repetitive Waveform

4.   Change the w(t) to a 2.4 KHz square wave to show the more complex spectrum and to see how harmonics of W(f) alias. Use dBV to see low level alias terms easier.
- Make a plot of the spectrum and identify several of the spectral components that are alias terms.
- What would the sample frequency have to be to eliminate aliasing?
- What circuit could you add to the sampler to reduce the effects of aliasing of the harmonics?

5.   Change the w(t) to a 2.4 KHz triangular wave shape.
- Are the alias terms lower than in part 4? Explain by comparing the Fourier transform of a square wave and a triangular wave.
- Again show your instructor and make plots in your lab notebook.

Information from LM311 data sheet

LM111/LM211/LM311
Voltage Comparator
1.0 General Description
The LM111, LM211 and LM311 are voltage comparators that have input currents nearly a thousand times lower than devices like the LM106 or LM710. They are also designed to operate over a wider range of supply voltages: from standard±15V op amp supplies down to the single 5V supply used for IC logic. Their output is compatible with RTL, DTL and TTL as well as MOS circuits. Further, they can drive lamps or re-lays, switching voltages up to 50V at currents as high as 50mA. Both the inputs and the outputs of the LM111, LM211 or the LM311 can be isolated from system ground, and the output can drive loads referred to ground, the positive supply or the negative supply. Offset balancing and strobe capability are provided and outputs can be wire ORíed. Although slower than the LM106 and LM710 (200 ns response time vs 40 ns) the devices are also much less prone to spurious oscillations. The LM111 has the same pin configuration as the LM106 and LM710. The LM211 is identical to the LM111, except that it's performance is specified over a þ25°C to +85°C temperature range instead of þ55°C to +125°C. The LM311 has a temperature range of 0°C to +70°C.

2.0 Features
- Operates from single 5V supply
- Input current: 150 nA max. over temperature
- Offset current: 20 nA max. over temperature
- Differential input voltage range: ±30V
- Power consumption: 135 mW at ±15V

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Normal Sampling without Aliasing

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    a) Observe the output PAM signal with an oscilloscope. Sketch the signal.

    Volts

    time

    b) Display the output spectrum using the FFT of the scope. Record the frequency and amplitude of each spectral line from DC to 25 KHz. You will use the Matlab program "lab4.m" to calculate the theoretical values to compare.

    c) Make appropriate plots in your lab notebook. Write a brief description of what the plots indicate.
    d) Show that a reasonable LPF can recover w(t).

Normal Sampling with Aliasing

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Normal Sampling with Aliasing of the Harmonics of a Repetitive Waveform

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